FOREST PEST MANAGEMENT

ARMILLARIA ROOT DISEASE AND AFFECTED ACREAGE ON THREE RANGER DISTRICTS ON THE BLACK HILLS NATIONAL FOREST

by

J.C. Holah
Plant Pathologist

United States Department of Agriculture

Forest Service

Forest Pest Management
Denver, Colorado

ARMILLARIA ROOT DISEASE AND AFFECTED ACREAGE ON THREE RANGER DISTRICTS ON THE BLACK HILLS NATIONAL FOREST

by

J.C. Holah
Plant Pathologist

Technical Report R2-55

September 1993

Renewable Resources
Rocky Mountain Region
USDA Forest Service
740 Simms Street
Golden, Colorado 80401

ACKNOWLEDGEMENTS

Many thanks to Keren Higgins, Bill Schaupp, and Steve Gaul for their field assistance. Thanks also to Judy Pasek, Terry Shaw, Pete Angwin, and Mike Sharon for reviewing this report.

ABSTRACT

Extensive ground surveys for Armillaria root disease on the Spearfish, Harney, and Custer Ranger Districts, Black Hills National Forest, were undertaken during the summers of 1992 and 1993. The purpose of these surveys was to determine: (1) the extent of the root disease within forest stands in terms of percent acreage affected; (2) the association, if any, between mountain pine beetle and Armillaria; and (3) if the disease is aggravated by intensive management activity. Fifty-three transect lines, approximately one-half mile in length and between 200 and 260 feet in width, were walked through a variety of ponderosa pine stands. The acreage affected was extreme on the Spearfish and Harney areas; 11% of the total acreage was occupied by an Armillaria disease center on the Spearfish district and 13% of the total acreage was diseased on the Harney district. The incidence of disease was high on both districts, as well; at least one Armillaria center was found on 100% of the Spearfish survey lines and on 77% of the survey lines on the Harney district. At least 77% of all small mountain pine beetle areas encountered on the Spearfish and Harney survey lines were in or near Armillaria centers. A negligible amount of root disease and bark beetles were found on the Custer district. Although the number of disease centers in recently managed and not recently managed stands was similar on the Spearfish district, twice as many acres were affected by the disease in areas that had been recently managed. Results unequivocally show that Armillaria root disease is widespread and generally affects a large number of acres per surveyed stand on the Spearfish and Harney districts, may increase following intensive management activities, and shares a close association with mountain pine beetle in a non-epidemic situation.

INTRODUCTION

Until recently, very little work has been done on Armillaria root disease in the Black Hills and its possible impacts. Roadside surveys (Lundquist, 1991) show that the disease is widespread in its distribution throughout the area, but until the series of surveys reported here, there has been little work on quantitative impacts of this disease on a stand level. Armillaria root disease, caused primarily by the fungus *Armillaria* sp. (the species has not been identified yet in the Hills), has been recognized as being present in the Hills since at least the 1930's. It has been consistently reported as a potentially important but largely 'unrecognized' disease due to confusion with mountain pine beetle mortality (Harney District Silvicultural Report 1930; Boldt, 1974). Previous studies on the mountain pine beetle have also noted that the beetle and disease are often co-occurring (Hinds *et al.*, 1984; Lessard *et al.*, 1985).

Three of the nine districts in the Black Hills National Forest were extensively surveyed for Armillaria in this project: Spearfish, Harney, and Custer Ranger Districts. The districts are contiguous and comprise nearly one-half million acres of forested land, primarily mature ponderosa pine stands. The Spearfish district covers the northern-most extent of the Black Hills, the Custer district covers a majority of the southern Hills, and the Harney district falls between the two.

The primary objectives were to determine: (1) if Armillaria root disease warrants attention on a stand level by land managers; (2) if the disease is aggravated by intensive management activity; and (3) if there is an association between mountain pine beetle and Armillaria root disease in terms of area in which they occur, not on an individual tree basis.

MATERIALS AND METHODS

The following three large units on the Spearfish district (Figure 1) were selected for the disease surveys: the Timon Timber Sale area (Area 1) and adjacent areas that had not been recently cut, the Pettigrew diversity unit (Area 2), and the Tollgate diversity unit (Area 3). The diversity units were surveyed because there was a prior need by the district to collect information on these particular areas. Twenty transect lines, comprising a total length of 11 miles, were walked throughout these three Spearfish units. Twenty-two transect lines on the Harney district (Figs. 2-4) and 11 transect lines on the Custer district (Fig. 5) were run in past and present timber sale areas. All transects were approximately a half-mile in length.

The width of individual survey lines was either 200 or 260 feet, depending on whether 2 or 3 people performed the survey. There was no previous knowledge on the condition of stands before surveying. Starting points were chosen such that survey lines would run through stands composed primarily of ponderosa pine that had some evidence of stand history, i.e., evidence of whether the area had been recently managed within the past 10-15 years or not. Starting azimuths were based on the contour of the area to be surveyed.

At each starting point, two or three surveyors walked parallel to each other at widths of approximately one chain (66 feet) apart. Each surveyor counted his or her paces with a tallywacker, and examined areas 66 feet to the left and right. The overlapping area of 66 feet between the surveyors was taken into account when data was recorded. When an area was encountered that exhibited symptoms of Armillaria root disease infection (patches of dead and dying trees, trees breaking from the roots or at the root collar, trees with poor crown conditions), root systems were checked for the fungus. An area was determined to have Armillaria if at least one living tree had white mycelial fans and/or rhizomorphs on its roots and if two or more living trees in the vicinity had root systems with excessive resinosus, a very strong indicator of infection. Only living trees were examined for root disease. Along each transect line, pace counts were used to record disease center entry and exit points. Exit points were recorded when all trees in front of a surveyor lacked root disease symptoms (i.e., poor crown conditions, yellowing of needles).

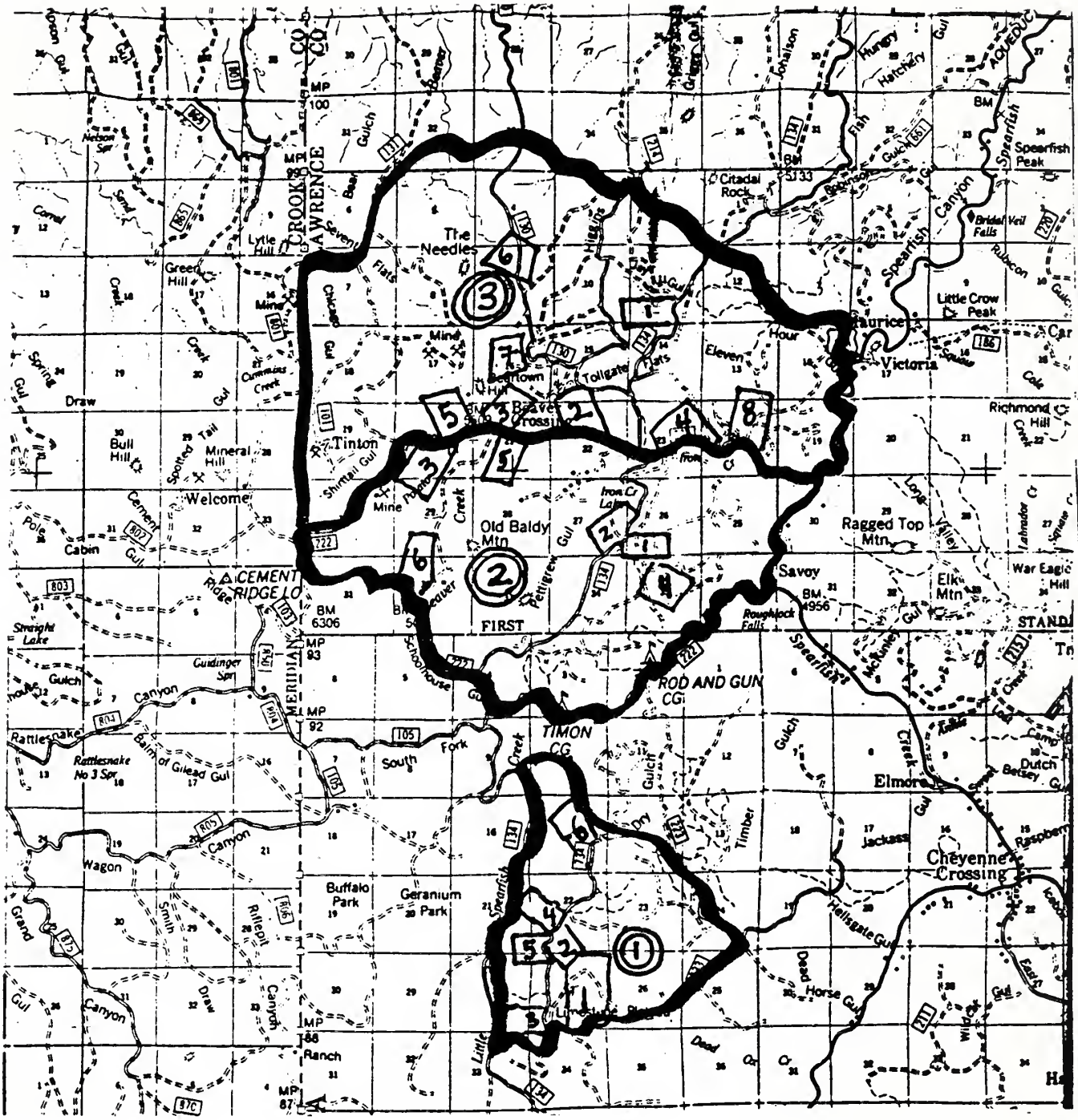

Figure 1: Locations of the three major areas surveyed (double-circled) on the Spearfish district and survey transects. Area #1 = Timon Timber Sale area and adjacent areas, Area #2 = Pettigrew diversity unit, Area #3 = Tollgate diversity unit.

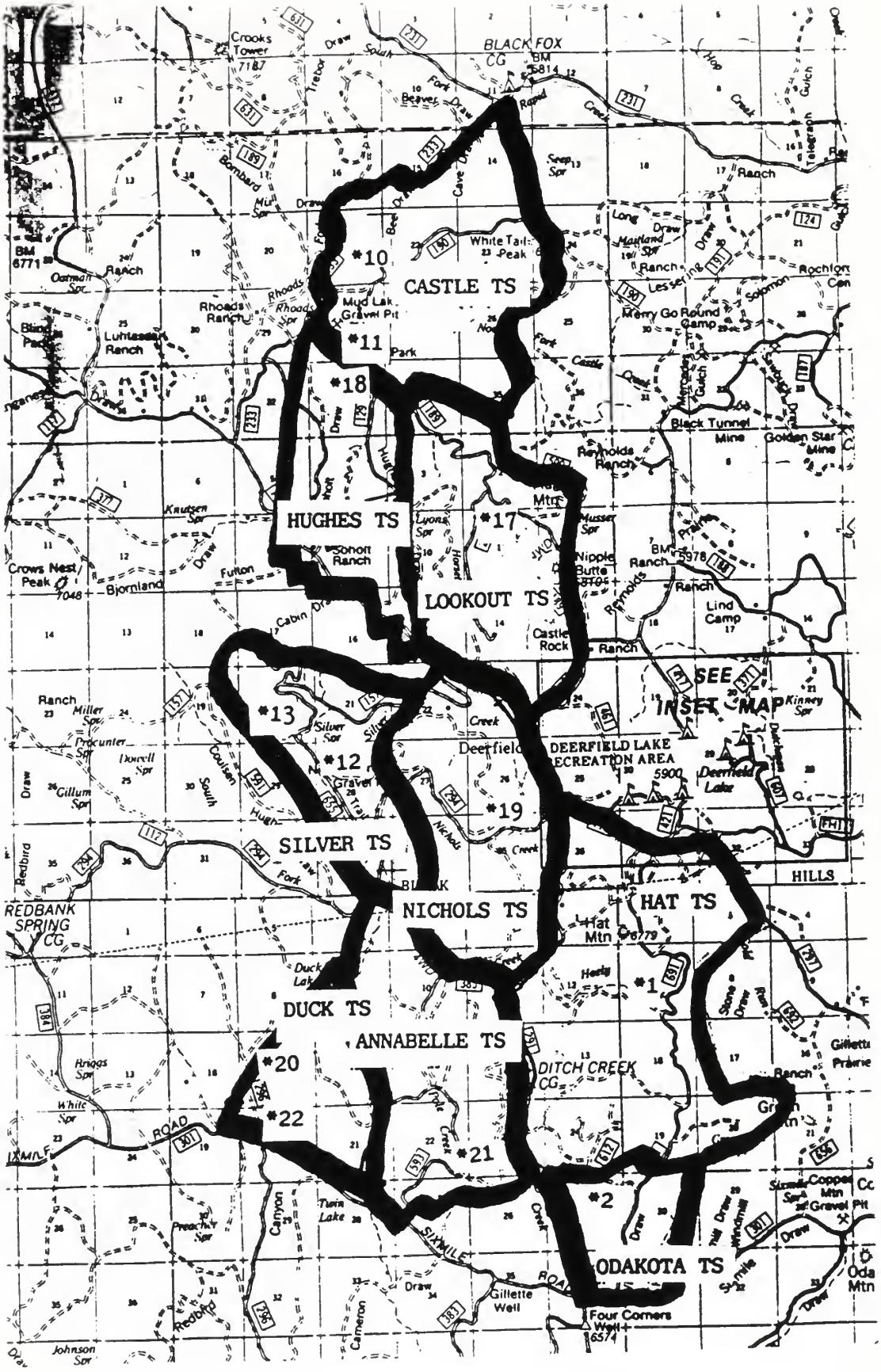

Figure 2: Locations of the timber sale areas and survey transects on the Harney District (in part).

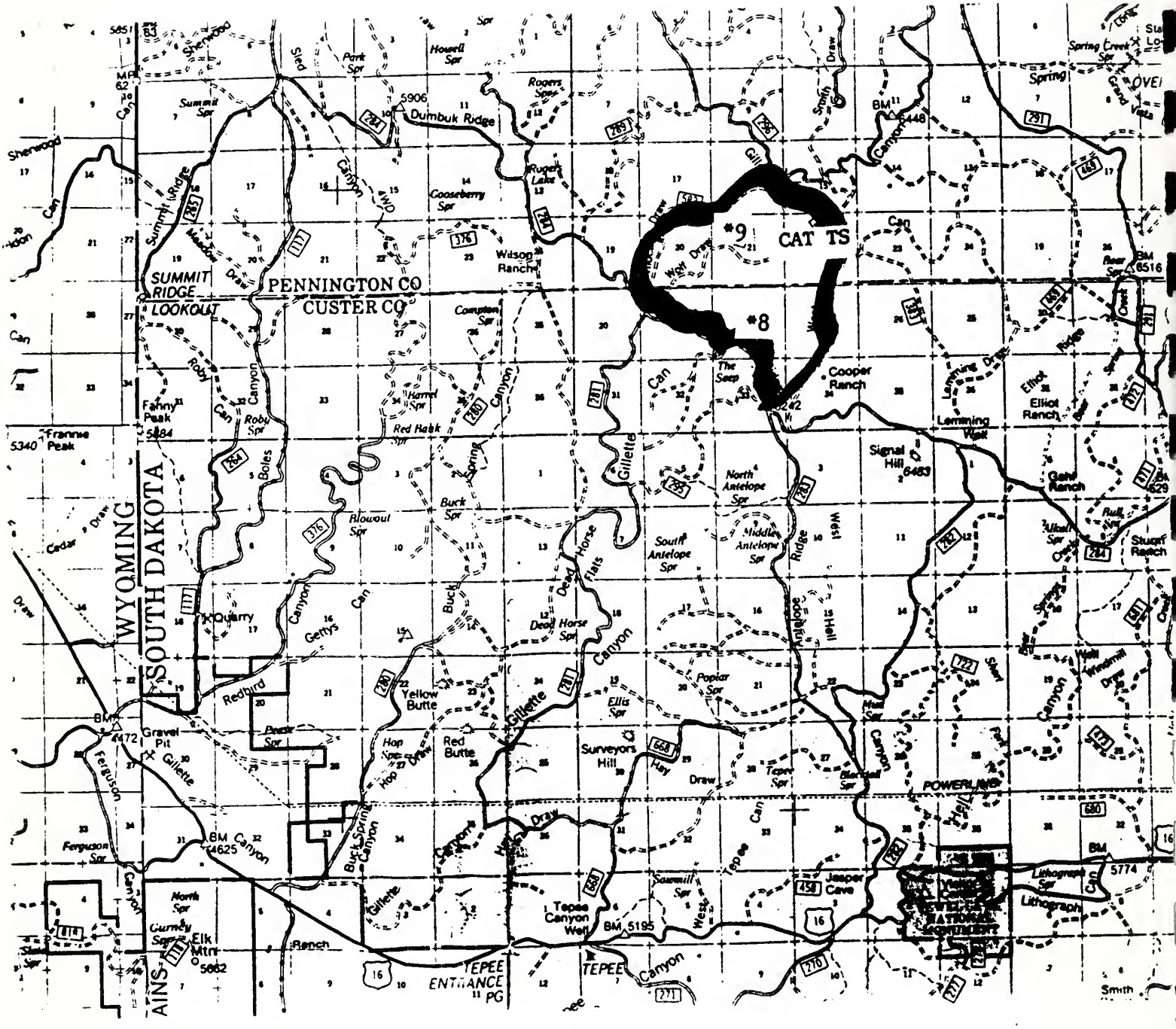

Figure 3: Locations of the timber sale areas and survey transects on the Harney District (in part).

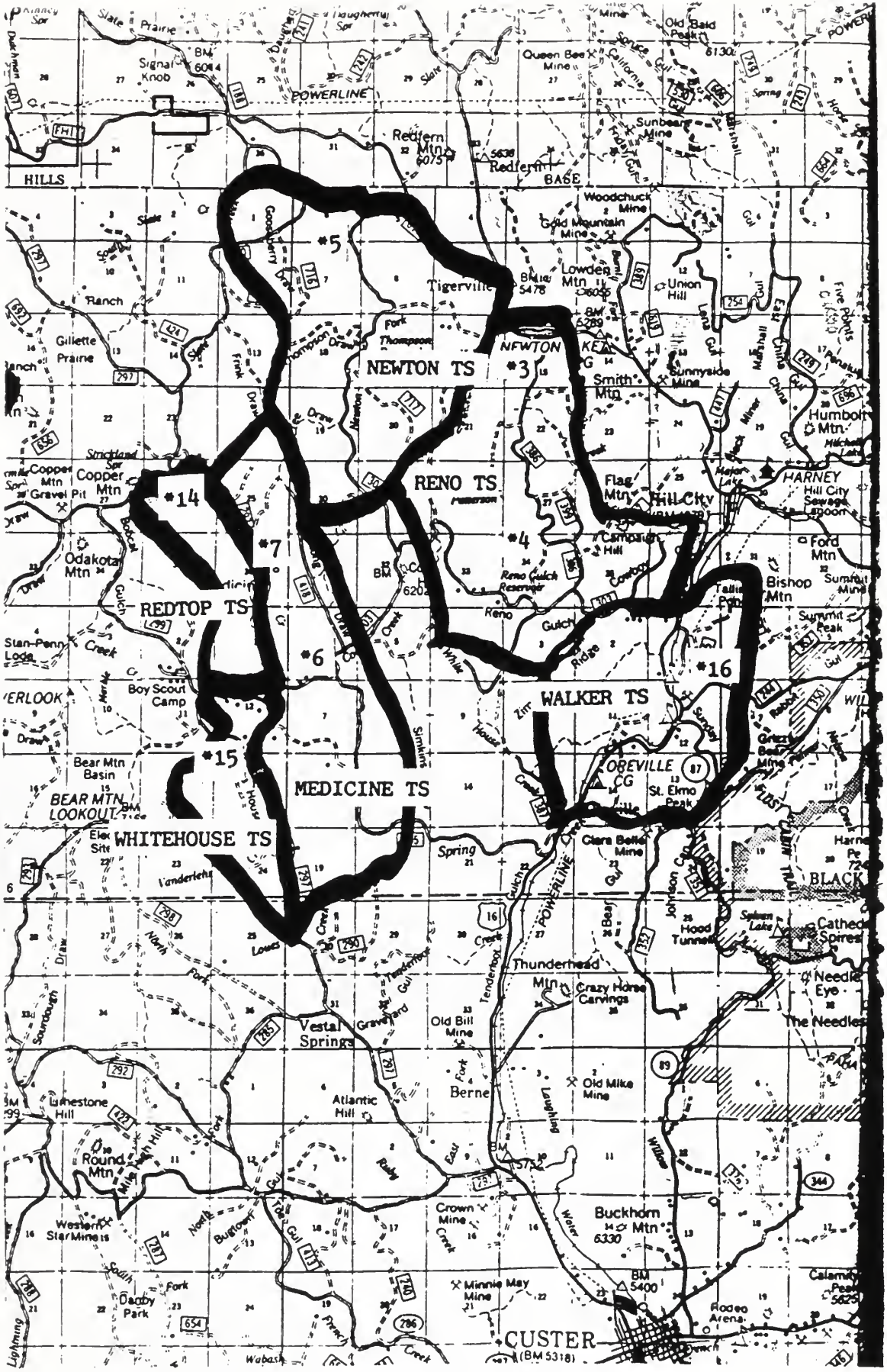

Figure 4: Locations of the timber sale areas and survey transects on the Harney District (in part).

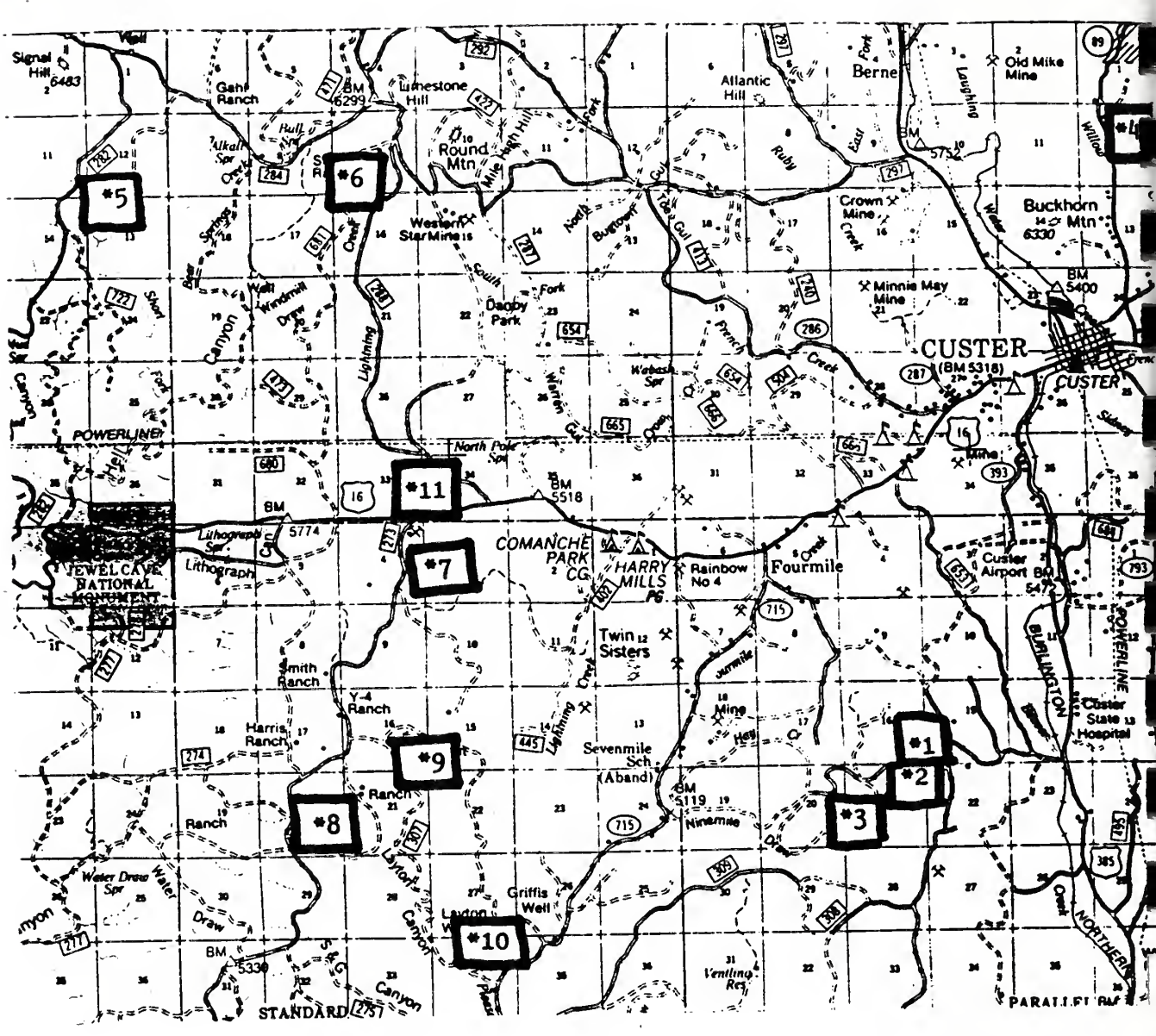

Figure 5: Locations of the transects walked on the Custer district.

The percentage of acreage infected with Armillaria was estimated by dividing the area along the transect within root disease centers by the total transect area. All trees along a transect line that had been mass attacked in the present or past by mountain pine beetles, as well as all trees which had been unsuccessfully attacked ('pitch-outs'), were recorded along the transect lines.

RESULTS AND DISCUSSION

1 - Is Armillaria root disease a problem that needs to be recognized?

Spearfish District

A summary of the root disease data from each transect line is presented in Table 1. Every transect intersected at least one Armillaria root disease center, indicating that the disease is quite widespread in the surveyed areas. An average of 5 disease centers were encountered along each of the 20 transect lines. A maximum of 10 centers was found in area 1 along transect 1 (transect 1-1). Transect 3-5 had the maximum area in root disease centers, 26% of the total acreage walked, while transects 1-3 and 3-4 had the least root disease with only 1% of the total acreage surveyed affected. The occurrence of root disease was very high on this district with approximately 11% of the 35 square mile area surveyed occupied by disease centers.

Harney District

Approximately 77% of the transects (17 of 22 transects) had at least one Armillaria center (Table 2). Transects "Odakota 2" and "Annabelle 21" had the most Armillaria centers with 9 centers each. Transect "Castle 11" had the greatest percentage of total acreage in disease centers, approximately 40% of the area surveyed. Most of the transects with the greatest amount of disease were found in the west and northwestern portions of the district. In the south and southeastern portions of the district, root disease was occasionally absent or present at low levels. The most surveyed acreage was affected on this district with an average of 13% of the 22 square mile area surveyed occupied by Armillaria root disease centers.

Custer District

Only 3 of the 11 survey lines on the Custer district contained Armillaria root disease, and 2 of these disease areas were extremely small, composed of only one or two trees. Only one transect line, transect #6, had a significant amount of root disease of nearly 5%. This transect line was on the northern end of the district (Figure 5). Because time was limited and little disease and insect activity was found, fewer transects were walked on this district as compared to the others.

Discussion

In the Pacific Northwest, laminated root rot, a common root disease on Douglas-fir, was found affecting approximately 5% of the Douglas-fir forested area in western Oregon and is considered one of the most serious economic threats to the timber industry (Gedney, 1981). Most survey lines on the Hills have much higher acreages affected by root disease and warrant notice in these areas, especially if the areas are to be managed for fiber production. Perhaps the best way to get an accurate prediction of what future volume impacts will be in an area with significant acreage in root disease centers is to use the Western Root Disease Model which has recently been linked to the Black Hills (Central Rockies) variant of Prognosis. In order to use this sort of assessment, root disease presence must be reported in the stand inventory data. The Forest Health Management personnel of the Rapid City Service Center are available to provide necessary training. The results of this survey will be used by researchers at the Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado to assess long term impacts of Armillaria in the Hills.

Table 1: Summary of root disease transect data on the Spearfish Ranger District. (Note: Transect "2-4" means the fourth transect in Area #2.)

Transect #	Total Acres Surveyed	# of Disease Ctrs.	Diseased Acreage (%)
1-1	26	10	14%
1-2	16	5	10%
1-3	12	1	1%
1-4	17	4	6%
1-5	12	3	3%
1-6	18	6	10%
2-1	16	5	7%
2-2	16	5	17%
2-3	16	7	19%
2-4	12	5	21%
2-5	12	2	8%
2-6	12	6	9%
3-1	13	2	3%
3-2	12	4	3%
3-3	12	3	15%
3-4	14	1	1%
3-5	17	6	26%
3-6	12	4	11%
3-7	12	8	5%
3-8	12	6	19%
TOTALS:	289	95	average: 11%

Table 2: Summary of root disease transect data on the Harney Ranger District. (Note: Names of transects refer to timber sale area locations. See Figs. 2-4 for transect locations.)

Transect	Total Acres Surveyed	# of Disease Ctrs.	Diseased Acreage(%)
Hat 1	16	1	< 1%
Odakota 2	17	9	12%
Reno 3	12	3	2%
Reno 4	12	1	2%
Newton 5	12	6	13%
Medicine 6	12	1	1%
Medicine 7	6	2	5%
Cat 8	12	0	0%
Cat 9	6	0	0%
Castle 10	12	5	18%
Castle 11	12	6	40%
Silver 12	12	6	22%
Silver 13	16	5	34%
Redtop 14	12	0	0%
Whitehouse 15	12	0	0%
Walker 16	12	0	0%
Lookout 17	12	5	26%
Hughes 18	12	3	26%
Nichols 19	13	2	25%
Duck 20	12	7	8%
Annabelle 21	12	9	23%
Duck 22	12	5	13%
TOTALS:	266	76	average: 13%

Current impacts on affected stands are reduced stocking, loss of regeneration, poor growth of diseased live trees, and rapid mortality of trees with advanced symptoms. In contrast with many of Armillaria's other host species, stringy decay throughout the roots and bole are found infrequently and usually only on pines that have been dead for a year or more. Mortality in ponderosa pine appears to be due to destruction of the living cambial layer in the roots by the fungus in conjunction with girdling resinosus lesions produced by the tree, rather than a weakening of the roots due to decay (Terry Shaw, pers. comm.).

Few options exist to control the spread of Armillaria in the Black Hills. Most control strategies are based on planting more resistant species in affected areas, an option not generally applicable to the Black Hills because most stands consist exclusively of naturally-regenerated ponderosa pine. Research in other areas has shown that pre-commercial thinning in diseased areas will not exacerbate disease, and may actually slow disease spread. This is presumably because thinned stands are more vigorous, less stressed from competition, and thus more able to resist the disease (Filip *et al.*, 1989; Johnson & Thompson, 1975). There also seems to be a correlation between frequency of stand entry and severity of root disease found in other areas. Intensity of management does not seem to be as closely correlated as frequency of management (Kile, 1991). Pulling stumps out of the ground is the most effective method of reducing the inoculum level of any site; however, it is often expensive. Stump removal is successful because the fungus cannot survive once exposed to the elements and is no longer able to infect adjacent healthy trees via root contacts and grafts.

2 - Is the disease aggravated by management activity?

Spearfish District

Approximately 44% more Armillaria centers were found in areas that had been recently managed; 56 centers were found in recently managed areas and 39 were found in areas that had not been recently managed. Both types of areas were surveyed equally in each of the three major areas. Infection center acreage was twice as great in areas that had been recently managed as opposed to those that had not (20.6 acres versus 10.8 acres). However, the results are difficult to interpret, because all areas surveyed had intensive management in the past. It is possible that areas that were not recently managed had the same number of stand entries, or perhaps more, in the past, as compared to those areas recently managed. On most districts, detailed stand histories prior to the 1970's were not available, although harvesting in the Hills has taken place since the late 1800's. The data does suggest that Armillaria centers are aggravated by management activity and that an increase in disease after such management activities may be expected. Research in other forests has shown a similar correlation between management activity and root disease incidence and severity (Shaw *et al.*, 1976; Wargo & Shaw, 1985). More work needs to be done on Armillaria dynamics in the Black Hills in order to assess what specific effects different management activities will have on disease.

Harney and Custer Districts

Because the majority of the stands in these areas had been entered several times or had been recently managed, it was difficult to establish catagories of recently versus not recently managed areas. Because these areas could not be clearly differentiated, assessment of differences in disease level with varying levels of activity was not attempted on these districts.

3 - Is there an association between incidence of mountain pine beetle and Armillaria root disease?

Spearfish District

Mountain pine beetle infestations were encountered 59 times on the series of transects. Generally, the mountain pine beetle areas were small, consisting of five or fewer attacked trees. Little recent beetle activity was noted throughout the survey. Of the 59 infested areas, 46 were in or near Armillaria root disease centers.

The probability of being in or near a disease center when an area of mountain pine beetle was found was 78%. Conversely, the probability of encountering mountain pine beetle-killed trees (or pitch-outs) when Armillaria was present was 48%. The data shows that many Armillaria root disease centers exist without being associated with mountain pine beetle, but most areas with mountain pine beetle also contain root disease.

Harney District

The results were surprisingly similar for the Harney District. Forty-three of the 49 mountain pine beetle areas encountered on the transect lines were small, consisting of five or fewer attacked trees. Of the 49 beetle areas, 33 were located in or near root disease centers, an association of 67%. However, if only the small, endemic mountain pine beetle areas are considered, the association with Armillaria is 77%, similar to what was found on the Spearfish District. On this District, also, the probability of finding a small area of mountain pine beetle when Armillaria was found was 43%. Results show here, too, that there are many Armillaria areas without beetles associated with them but few small mountain pine beetle areas that are not associated with Armillaria centers. However, when the mountain pine beetle infestations were large (usually more than five recently attacked trees) and the beetles were in an epidemic state, the association did not seem to hold.

Custer Ranger District

Only one mountain pine beetle area was found on the Custer District transects and it was not associated with an Armillaria center.

Discussion

Previous work on the Black Hills has shown an association between the mountain pine beetle and Armillaria (Eckberg, *et al.*, in press; Hinds *et al.*, 1984; Lessard, 1982; Lessard *et al.*, 1985). However, the majority of these studies focused on finding both agents in a single tree. This project focused on whether or not the beetle and disease were associated by area, and the data clearly showed that they were when the beetles were not in a full epidemic state. The few recently mass-attacked trees that were found on transects usually bordered Armillaria centers, but were relatively healthy trees, not trees with visibly advanced symptoms of root disease. Previous studies in other forests have suggested that understanding the associations between the mountain pine beetle in its endemic state and Armillaria root disease may lend some important clues as to when and why outbreaks are triggered (Tkacz & Schmitz, 1986).

CONCLUSION

Armillaria root disease occupies large areas in the Spearfish and Harney Districts, with disease centers comprising well over 10% of the 57 square miles that were surveyed. The disease is also widespread throughout the areas surveyed with Armillaria centers being found on the majority of the transects walked. The Custer District seemed, overall, to have a low incidence of root disease, though more surveys are needed there to locate the isolated hot spots of Armillaria which may occur on the northern end of this District. It is interesting to speculate on why Armillaria is relatively rare in the southern part of the Custer District when incidence and severity of the disease is so high in other parts of the Hills. Various hypotheses may involve differences in soil type, higher frequency of fire, and differences in tree physiology. Perhaps the most feasible explanation, however, is that much of the southern Hills may have had a much sparser forest in the past. Thus the fungus, which does not seem to be able to infect hosts via spores, may not have established itself in the southern Hills, and will perhaps not establish itself for a very long period of time.

The specific impacts on the individual stands will be determined by the management defined for the area. However, recognition of the possible severity of the root disease should be considered when defining management objectives and planning management activities. Although Armillaria does have a negative

impact on sawtimber volume for a particular area, the presence of the disease may be a positive impact for other resources, such as wildlife, as it diversifies stand structure, promotes growth of hardwood species (especially birch) and provides a variety of habitats in dead and down wood. Most importantly, an accurate accounting of where, and to what extent, the disease is present needs to begin in order to get reliable estimates of the current timber base affected and what the future available timber base for specific areas will be.

Additional work needs to focus on the association of mountain pine beetle and Armillaria as the management of one may affect the dynamics of the other. Because of the close association between the mountain pine beetle and Armillaria when the beetle is not in an epidemic state, it may be useful to take into account, when predicting when an epidemic will start, where an epidemic will start, and what will be the direction of epidemics. In the future perhaps it will be possible to answer such questions as: (1) Are heavily diseased stands foci for beetle epidemics? (2) Are Armillaria-free stands more resistant to beetle attacks as compared to similar stands with Armillaria?

Areas impacted by Armillaria appear to have been frequently confused with areas infested by mountain pine beetle, probably because they often occur in the same area and patches of Armillaria-caused mortality can look like beetle-caused mortality to the untrained eye. However, it is extremely important to distinguish the two, as management activities will affect the two agents differently. Futhermore, it must be kept in mind that Armillaria is a chronic agent that will kill trees over extended periods of time, whereas beetle-caused mortality is generally concentrated over short periods of time.

REFERENCES

Boldt, C. E. 1974. Silviculture of ponderosa pine in the Black Hills: the status of our knowledge. USDA Forest Service, Research Paper RM-124. Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO. 45 p.

Eckberg, T.C, J.M. Schmid, S.A. Mata, and J.E. Lundquist. (In press). Focus trees for the mountain pine beetle in the Black Hills. USDA Forest Service, Research Note, Rocky Mountain Forest and Range Experiement Station, Ft. Collins, CO.

Filip, G.M., D.J. Goheen, D.W. Johnson, and J.H. Thompson. 1989. Precommercial thinning in a ponderosa pine stand affected by Armillaria root disease: 20 years of growth and mortality in central Oregon. Western J. Applied Forestry 4: 58-59.

Gedney, D.R. 1981. The occurrence of laminated root rot on non-federal timberland in Northwest Oregon, 1976. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Note PNW-381.

Harney District Silvicultural Report, 1930. Archives file.

Hinds, T.E., L.R. Fuller, E.D. Lessard, and D.W. Johnson. 1984. Mountain pine beetle infestation and Armillaria root disease of ponderosa pine in the Black Hills of South Dakota. USDA Forest Service, Technical Note R2-30. Timber, Forest Pest, and Cooperative Forestry Management, Rocky Mountain Region, Lakewood, CO. 7 p.

Johnson, D.W. and J.H. Thompson. 1975. Effect of precommercial thinning on ponderosa pine, *Pinus ponderosa*, infected with *Armillaria mellea*. Plant Dis. Reptr. 59: 308-309.

Kile, G.A. 1991. Ecology and disease in natural forests. In: *Armillaria Root Disease*, Shaw III, C.G. and G.A. Kile, eds. USDA Forest Service, Agricultural Handbook No. 691: 102-121.

Lessard, E.D. 1982. Factors affecting ponderosa pine stand susceptibility to mountain pine beetle in the Black Hills. USDA Forest Service, Technical Report R2-26. Timber, Forest Pest, and Cooperative Forestry Management, Rocky Mountain Region, Lakewood, CO. 16 p.

Lessard, E.D., D.W. Johnson, T.E. Hinds, and W.H. Hoskins. 1985. Association of Armillaria root disease with mountain pine beetle infestations on the Black Hills National Forest, South Dakota. USDA Forest Service, Technical Report 85-4. Forest Pest Management, Lakewood CO. 6 p.

Lundquist, J.E. 1991. Distribution of Armillaria root disease in the Black Hills. USDA Forest Service, Technical Report R2-49. Forest Pest Management, Lakewood, CO. 10 p.

Shaw III, C.G., L.F. Roth, L. Rolph, and J. Hunt. 1976. Dynamics of pine and pathogen as they relate to damage in a forest attacked by Armillaria. Plant Dis. Reptr. 60: 214-218.

Tkacz, B.M. and R.F. Schmitz. 1986. Association of an endemic mountain pine beetle population with lodgepole pine infected by Armillaria root disease in Utah. USDA Forest Service, Research Note INT-353. Intermountain Forest and Research Experiment Station, Ogden, UT. 7 p.

Wargo, P.M. and C.G. Shaw, III. 1985. Armillaria root rot: the puzzle is being solved. Plant Disease 69(10): 826-832.